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SPECIAL REPORT

THE EFFECTS ON MAMMALS OF DDT USED IN THE CONTROL OF TUSSOCK MOTHS IN NORTHERN IDAHO

WILDLIFE INVESTIGATIONS ON PUBLIC LANDS
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The Effects on Mammals of DDT Used in the Control of Tussock Moths in Northern Idaho

In May and June, 1947, approximately 390,000 acres of forested lands in northern Idaho were sprayed with DDT to control the tussock moth (Hemerocampa pseudotsugata). Studies of the effects of this large-scale use of DDT on the mammal population of the area sprayed are reported here.

The DDT was applied by airplanes operated by the Central Aircraft Corporation, Washington, and the Johnson Flying Service, Montana. The project was administered by the Forest Service with the cooperation of the Bureau of Entomology and Plant Quarantine. (For administrative and operational details see U. S. Forest Service report in process of preparation.)

Several investigations of the effects of DDT on fish and wildlife have been conducted in other parts of the country, particularly in the eastern United States. Reports of these studies have been summarized by Cottam and Higgans (1946), and by Nelson and Surber (1947). Of the many investigations reported, only a few were concerned particularly with the effects of DDT on mammals (see tables 1 and 2). Stickel (1946) found no adverse effects on the short-tailed shrew (Blarina sp.) and the deer mouse (Peromyscus leucopus) from DDT applied at the rate of two pounds per acre in Maryland. Couch (Cottam and Higgans, op. cit.) observed that raccoons showed no evidence of being affected by eating crayfish killed by DDT applied at the rate of 0.5 to 0.2 pounds per acre in Illinois. Vertebrates were apparently unaffected in Oregon with less than one pound of DDT per acre and in Kentucky with 0.4 pounds per acre (Cottam and Higgans, op. cit.). Mammals were apparently unaffected by DDT in 2- and 3-pound doses in South Carolina (Nelson and Surber, op. cit.).

Laboratory studies have been made by Treichler and Hoffman to determine the effect of DDT on mammals (Cottam and Higgans, op. cit.). They mixed DDT in the diet of wild-trapped field mice. After 30 days, no apparent toxic effect was noted in mice receiving food composed of 0, 0.01, 0.02, 0.04, and 0.10 percent DDT by weight. Two out of five mice receiving a 0.20% diet of DDT died. Five out of five mice receiving a 0.40% diet died. A similar test was made on white-footed mice. These were much less susceptible to DDT poison. Ten field mice in habitat cages sprayed with DDT at the rate of five pounds per acre showed no evidence of toxicity after 30 days, even though they were fed DDT-sprayed oats during the last nine days of the experiment. Four cottontail rabbits were fed a 0.20% DDT diet. One showed tremors on the eleventh day, but recovered.

The others appeared unaffected. Four other rabbits were fed a 0.40% diet. Three showed tremors on the third day. Two died, one on the fifteenth day and one on the twentieth day. In another test with cottontails, DDT was administered by means of a stomach tube in six dose levels ranging from 500 milligrams to 2,500 milligrams per kilogram of body weight. There were no symptoms of poisoning at levels below 1,500 milligrams. One rabbit showed tremors at the 1,500 milligram level on the second day, but recovered. Two of the four animals on the 3,000-milligram dosage died on the third and thirteenth days, respectively. Two of the three animals on the 2,500-milligram dosage died on the seventh and twelfth days, respectively.

Coburn and Ediger (Nelson and Surber op. cit.) sprayed a pastureland type of habitat at rates of five and 7½ pounds per acre. All ten of the cottontails in the experimental plot died within nine days after losing an average of 9.1 ounces in weight.

All field investigations to date have indicated that mammals are apparently unaffected by DDT as used in pest-control operations. Obviously the mammals are not immune to the poison, as shown by the laboratory experiments. It is apparent, therefore, that the mammals are simply not acquiring lethal amounts of the poison. This may result from either of two causes or a combination of both. Either there is not a lethal amount of the poison available to the mammals, or the animals are not assimilating sufficient quantities to kill them, or both of these factors are causative.

It is of interest to compute the quantities of poison it would take in spraying an area to make lethal doses available to the mammals there. These computations can be approximated with data available from the papers of Stickel (op. cit.) and Coburn and Treichler (1946). For example, laboratory tests showed that the lethal threshold for cottontail rabbits was approximately four grams of DDT consumed during a 34-day period. Normally these rabbits occur under dense canopy and obtain their food from the lowest stratum of the vegetative cover. Stickel found that only 0.4 percent of DDT sprayed over an area reached this lower stratum in dense woods. Under those conditions it would be necessary to spray 1000 grams or 2.205 pounds over each rabbit's territory in order to place the minimum lethal dosage within reach of the rabbits. Hamilton (1939) gives the range of cottontail rabbits (Sylvilagus floridanus mallurus) as three acres for females and eight acres for males. The rate of application over these areas required to place minimum lethal doses within reach of the rabbits would be 0.735 pounds per acre for females and 0.276 pounds per acre for males. Table 3 shows the rates of application necessary to place minimum lethal doses in reach of the three animals tested in the laboratory.

Table 1.--Field studies of the effects of DDT on mammals

Kinds of Mammals	Dosage	Results	Locality of Study	Lit. Cit.
Field Studies				
Deer mouse (Peromyscus leucopus)	2 lbs. per acre	No appreciable effect	Maryland	Stickel, 1946
Short-tailed shrew (Blarina sp.)				
Raccoons	Eating crayfish killed by 0.5-0.2 lbs. per acre	No appreciable effect	Illinois	Cottam and Higgans, 1946
"Vertebrates"	Less than 1 lb. per acre	No appreciable effect	Oregon	Cottam and Higgans, 1946
"Vertebrates"	0.4 lb. per acre	No appreciable effect	Kentucky	Cottam and Higgans, 1946
"Mammals"	2 and 3 lbs. per acre	No appreciable effect	South Carolina	Nelson and Surber, 1947

Of course, the factors involved in these computations are subject to wide variation, and we have here only rough indications of the true facts of the case. The rates of application shown in table 3 are lower than those used for most practical control measures. It is apparent, therefore, that the lack of deaths among mammals under conditions of DDT use results from failure of the mammals to obtain the poison from their surroundings, not from a lack of lethal quantities within their reach.

The tussock moth control program in Idaho offered the first opportunity in the Rocky Mountains for investigations of the effects of a DDT project on mammalian life. Efforts to realize full advantage of this opportunity were considerably hampered by the fact that operations of the project were entirely independent of the investigational work. There was no opportunity of modifying operations for the benefit of the study. It was even impossible to know from day to day just when and where within the project area spraying operations would occur. These conditions were particularly prevalent during the early stages of the project when most of the investigations of mammals were made.

As a result of the obstacles described, original plans were considerably modified as the study progressed. Instead of having three study plots inside the sprayed area and a control plot

Table 2.--Laboratory studies of the effects of DDT on mammals

Kinds of Mammals	Dosage	Results	Locality of Study	Lit. Cit.
Field mice (*Nuciatus Pennsylvanicus*)	Percentage of food by weight: 0, 0.01, 0.02, 0.04, 0.10, 0.20, 0.40	No appreciable effect from 1st five dosages; 0.20 dosage: 2 out of 5 mice died; 0.40 dosage: 5 out of 5 mice died	Maryland	Coburn and Treichler, 1946
White-footed mice (*Peromyscus leucopus*)	Similar to above	Showed less susceptibility than field mice	Maryland	Coburn and Treichler, 1946
Field mice	Habitat cage sprayed at rate of 5 lbs. per acre. Fed DDT-sprayed oats during last 9 days of 30-day experiment.	No appreciable effect	Maryland	Coburn and Treichler, 1946
Cottontail rabbits (*Sylvilagus floridanus.*)	0.20% DDT diet	1 of 4 showed tremors on 11th day but recovered. Others showed no appreciable effect	Maryland	
Cottontail rabbits	0.40% DDT diet	3 of 4 showed tremors. 1 each died on 15th & 20th day, respectively	Maryland	Coburn and Treichler, 1946
Cottontail rabbits	Administered by stomach tube:		Maryland	Coburn and Treichler, 1946
	500 mg. per kg. of body wt.	No appreciable effect		
	750 mg. per kg. of body wt.	No appreciable effect		
	1000 mg. per kg. of body wt.	No appreciable effect		
	1500 mg. per kg. of body wt.	1 of 3 showed tremors, recovered		
	2000 mg. per kg. of body wt.	2 of 4 died		
	2500 mg. per kg. of body wt.	2 of 3 died		
Cottontail rabbits	5 & 7½ lbs. per acre in pastureland type of habitat	10 of 10 died within 9 days	Maryland	Nelson & Surber, 1947

outside, as originally planned, there were only two plots. One was near the center of the largest single unit treated, and the other was on the edge of the same unit. These plots will be referred to as Plot 1 (near the center of the unit) and Plot 2 (on the edge of the unit).

Both plots were in that section of northern Idaho where the Palouse hills of the Columbia plateau meet the western foothills of the Bitterroot Mountains near Moscow, Idaho. The Columbia plateau in this area is composed of rolling hills of loess. Originally these hills bore a bunch-grass type of vegetation, but now most of it is under cultivation and devoted to the production of dry-land crops, principally wheat, peas and hay. The foothills rise above the eastern rim of the Palouse in abrupt fashion as granitic outcroppings. These hills are covered with forests of Douglas-fir, ponderosa pine, and Engelmann spruce, with admixtures of western redcedar, grand-fir, alpine fir, western larch, lodgepole pine and western white pine. Most of the timber has been cut over. This has opened the forest canopy to permit heavy growth of an understory of willow, Oregon grape, rose, spirea, ocean spray, service berry, chokecherry, maple, buffalo berry, Menziesia, kinnikinnick, huckleberry, and snowberry.

There is no sharp line between the vegetation of the Palouse farmlands and that of the forested mountains. Many islands and peninsulas of woodland extend for several miles out into the Palouse. The islands vary in size from an acre or less to several hundred acres. Conversely, there are many clearings, either natural or artificial within the foothill area. These also vary in size.

Table 3.--Application rates required to place lethal dosage of DDT in reach of three mammals in natural habitats

Species	Minimum Lethal DDT Dosage	Normal Habitat Cover Density°	Range of Individual Animal	Required rate of spray to place minimum lethal dose in reach of animal
Cottontail Rabbit	4.0 grams in 34 days	Dense	3 acres (females)	0.735 lbs. per acre
			8 acres (males)	0.276 lbs. per acre
Field mice	0.29 grams in 28 days	Sparse	0.1 acre	0.256 lbs. per acre
White-footed mouse	0.20 grams in 30 days	Intermediate	0.1 acre	0.441 lbs. per acre

°For dense cover the rate of effective deposition of poison is 0.4 percent of the amount actually sprayed. For sparse cover the effective rate is 2.5 percent. (Stickel, 1946.)

As a result of the irregular distribution of trees, the areas treated for tussock moth were also irregular in size and outline. Since the moth affected the Douglas-fir primarily, treatment areas generally conformed to the distribution of that species. Douglas-fir occurs along the lower mountain slopes in a belt irregular in width and with many interfingerings with an arborvitae-white pine belt above and a ponderosa pine belt below. In the treatment area, the largest single expanse of treated area occurred in a widespread Douglas-fir zone lying between Moscow Mountain and the higher mountains to the east. Moscow Mountain is an outpost mountain located west of the main mountain mass and connected with it by a long, low ridge. Both slopes of the connecting ridge were infested with tussock moths in a solid expanse of about 50 square miles.

Plot 1 was located near the center of the area just described, at the head of Flat Creek. It was a square plot covering 40 acres. Flat Creek entered the plot near the northeast corner and left it near the southwest corner. The plot occupied the slopes on either side of the creek. One slope was predominantly north-facing and the other faced south. The north slope and stream bottom bore a forest of western redcedar with a few white pine and Douglas-fir. The redcedar along the bottom gave way to Douglas-fir on the south slope with a few ponderosa pines along the tops of the ridges.

The area was logged about 17 years ago and there is much widespread slash littering the forest. Logging roads were constructed along the main drainages. These are not maintained and are gradually reverting to natural vegetative cover. Meanwhile, they form openings in which grasses and other low plants grow. These roads are used by cattle, elk and deer for pathways and for the grazing they afford.

Thirty-six Sherman type live traps were set in a grid pattern over the 40-acre plot at four-chain intervals. They were baited with peanut butter, rolled oats and bacon at first, then with rolled oats only when it was observed that the peanut butter and bacon were not being eaten. It was intended that trapping would be done for three nights before the area was sprayed with DDT, and for three nights after spraying. It was one of the unfortunate results of lack of coordination between the investigational project and the operational project that Area 1 was sprayed on the first day it was trapped. Thus no pre-spraying check was obtained. However, data from the three days of trapping on Area 1 immediately after it was sprayed are of interest in supplementing the information obtained from Area 2 where greater success in the coordination of the spraying and trapping was experienced.

Plot 2 was located on the southeast shoulder of East Moscow Mountain. Although there is more southern exposure on Plot 2 than on Plot 1, its vegetative cover is similar. There is perhaps less redcedar and more western larch, probably indicating a somewhat warmer and drier site than Plot 1. The principal difference from Plot 1, however, was the fact that Plot 2 lay

at the edge of the forest adjacent to a brush field which had been created approximately fifteen years previously by clearing and burning. Apparently an attempt had been made to clear the land for agriculture. The effort had been abandoned, however, and the clearing was being obliterated with dense growths of willow and scattered young ponderosa pine and Douglas-fir. This brushy habitat extended into the forest's edge and constituted a dense understory of several species of shrubs.

Plot 2 was eight chains by fourteen chains (11.2 acres) in size. Sherman type live traps were set in a grid pattern at two-chain intervals.

Sixteen kinds of mammals were observed in the treated area before, during and after spraying. Most of them were observed only casually in the course of trapping activities. However, the fact that the observer was in the field and covering plots of ground in fairly detailed fashion almost daily during and after spraying operations provided opportunity for obtaining evidence of any outstanding effects such as carcasses of dead animals, abnormal actions of animals, and the like. A report of general observations follows the report of trapping.

With 76 traps and 428 trap-nights on Plots 1 and 2, 67 different mammals were caught and released 147 times. Five species were represented: chipmunks (Eutamias ruficaudus simulans and Eutamias amoenus luteiventris), white-footed mouse (Peromyscus maniculatus artemisiae), red-backed mouse (Clethrionomys gapperi saturatus), and jumping mouse (Zapus princeps), in that order of abundance. No distinction was made in the field between the two species of chipmunks and they are discussed here collectively. Chipmunks were more numerous than all three of the other species together. Forty-four chipmunks were caught and released 100 times, 18 white-footed mice 42 times, four red-backed mice four times, and one jumping mouse once.

Plot 1 had a much smaller population than Plot 2. In terms of animals caught per trap-night per acre, there were 3.83 times as many chipmunks and six times as many white-footed mice on Plot 2 as on Plot 1. There were four red-backed mice caught on Plot 2, none on Plot 1. On the other hand, the only jumping mouse recorded was caught on Plot 1. (A later attempt to retrap the jumping mouse with fifteen traps set for two nights was unsuccessful. However, a red-backed mouse was caught, indicating that this species was not entirely absent on Plot 1.)

Of all the mammals trapped, only the chipmunks on Plot 2 were sufficiently numerous to provide a statistical basis for evaluating the effects of DDT on a wild mammal population. A comparison of numbers of chipmunks before and after spraying is pertinent. Plot 2 was trapped on four consecutive nights (May 21 - 24 inclusive) before that area was sprayed on May 28, and on four nights (May 31, June 1 - 3 inclusive) after it was sprayed. An index of the relative abundance of chipmunks before and after

spraying is furnished by the number of animals caught per trap-night. In the pre-spray trapping, the animals caught per trap-night was 0.3375. In the post-spray trapping, it was 0.2125. This is a decrease in population of 34.1 percent.

Probably this decrease in the chipmunk population cannot be attributed to the effects of DDT. Rather, it probably results from a combination of other factors, particularly variations resulting from the trapping itself. For one thing, several deaths resulted from confinement in the traps. During the pre-spray trapping, two chipmunks were found dead in the traps and four were in extremely lethargic condition. Only one of the four was trapped later, indicating that the other three probably died. During the post-spray trapping, two dead chipmunks and four lethargic ones were found in the traps--the same number that were found earlier. That the deaths were not results of DDT poisoning may be assumed on the basis that (1) the deaths occurred before as well as after spraying, (2) the symptoms were the opposite of those elicited by DDT poisoning (lethargy rather than nervousness and tremors), and (3) such deaths occur commonly in most live-trapping projects entirely unassociated with the use of DDT.

A second possible factor contributing to the decrease in numbers of chipmunks was the fact that the height of the breeding season was past, as evidenced by the inactive breeding condition of the males and the relatively few lactating females. Thus the population was probably on a natural decline from its annual peak.

A third possible explanation for fewer chipmunks caught after spraying is the fact that, while they had been set in the mornings before spraying, the traps were set in the afternoon during the post-spray trapping. This allowed more nocturnal species (white-footed mice and red-backed mice) to enter the traps, leaving fewer traps available for catching the diurnal chipmunks. This explanation is substantiated by the fact that nearly three times as many white-footed mice and red-backed mice were caught after spraying as before.

A fourth argument against the deaths being a result of DDT is the fact that no dead chipmunks were seen outside the traps and none showed symptoms of DDT poisoning. All deaths and sickness were associated directly with trapping activities. Animals affected by the poison probably would be readily observed in the field because of the striking nature of the symptoms and the diurnal habits of the chipmunks.

It is concluded, therefore, that the DDT applied at the rate of one pound per acre had no appreciable effect on the chipmunks. This conclusion probably applies also to white-footed mice and red-backed mice. It is almost certain that if any effect was felt at all, it was too slight to influence the population as a whole.

General observations of other mammalian forms revealed no evidence of poisoning by DDT. Pine squirrels (Tamiasciurus hudsonicus) were fairly abundant before, during and after DDT was applied. One family of four young squirrels were observed in a rotten